PATENT ABSTRACTS OF JAPAN

(11)Publication number : 09-295891

(43)Date of publication of application : 18.11.1997

(51)Int.Cl. C30B 28/00
C30B 29/06

(21)Application number : 08-132846

(22)Date of filing : 30.04.1996

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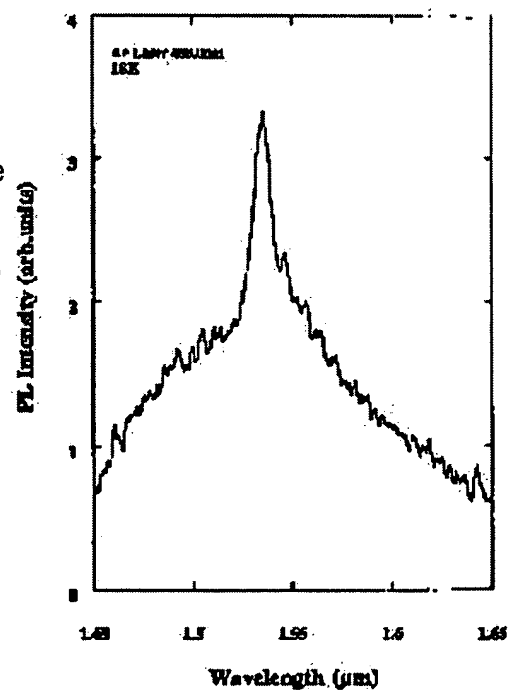
(54) RARE EARTH ELEMENT-DOPED-SILICON MATERIAL AND ITS PRODUCTION

(57)Abstract:

PROBLEM TO BE SOLVED: To produce a rare earth element-doped Si material, having a high luminous efficiency and applicable to an optical device and provide a method for producing the Si material.

SOLUTION: This rare earth element-doped Si material is prepared by doping an Si material formed of an ultramicro-crystal with a rare earth element and is capable of manifesting the visible light emission of the Si material formed of the ultramicro-crystal and the infrared and visible light emissions of the rare earth element. The ion implantation of the rare earth element into a high-purity amorphous Si thin film can be carried out to produce the rare earth element doped Si material by using atoms of the rare earth element as nuclei or the laser ablation can directly be used to produce the rare earth element- doped Si material from an Si target containing the rare earth element added thereto.



LEGAL STATUS

[Date of request for examination] 22.03.2001

[Date of sending the examiner's decision of

rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	3600872
[Date of registration]	01.10.2004
[Number of appeal against examiner's decision of rejection]	
[Date of requesting appeal against examiner's decision of rejection]	
[Date of extinction of right]	

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the rare-earth-elements dope Si ingredient which enables manufacture of optical devices, such as optical memory, at a detail, and its manufacture approach further about the silicon (Si) ingredient which added rare earth elements (dope), i.e., a rare-earth-elements dope Si ingredient, and its manufacture approach.
[0002]
[The background and Object of the Invention] of invention Conventionally, it is known that the atom of the rare earth elements added by the semi-conductor shows the sharp infrared rays and sharp visible luminescence by 4f inner shell transition.
[0003] It is hardly dependent on a semi-conductor slack parent ingredient or temperature, and the wavelength location and full width at half maximum of atomic luminescence of such rare earth elements show a fixed value.
[0004] Especially the erbium (Er) was what emits light on the wavelength of 1.55 micrometers in rare earth elements.
[0005] Here, since the wavelength of 1.55 micrometers is the minimum transfer loss wavelength of an optical fiber, the application to the fiber optics communication of luminescence of an erbium is expected greatly. That is, in current, it is anxious for development of the optical device using the optical property of such rare earth elements.
[0006] This invention is made in view of the above-mentioned background, and its luminous efficiency is high and it tends to offer the applicable rare-earth-elements dope Si ingredient and its manufacture approaches to an optical device, such as optical memory.
[0007]
[Means for Solving the Problem] In order to attain the above-mentioned purpose, the rare-earth-elements dope Si ingredient in this invention dopes rare earth elements into Si ingredient formed with the super-microcrystal, and enables it to discover visible luminescence of Si ingredient, the infrared rays of the above-mentioned rare earth elements, and visible luminescence which were formed with the above-mentioned super-microcrystal.
[0008] Moreover, an erbium is doped as rare earth elements into Si ingredient formed with the super-microcrystal.
[0009] Furthermore, the manufacture approach of the rare-earth-elements dope Si ingredient by this invention carries out the ion implantation of the rare earth elements into the amorphous silicon thin film of a high grade, uses the atom of rare earth elements as a nucleus, and manufactures a rare-earth-elements dope Si ingredient.
[0010] The manufacture approach of the rare-earth-elements dope Si ingredient by this invention manufactures a rare-earth-elements dope Si ingredient directly from Si target of rare-earth-elements addition further again using laser ablation.
[0011] Moreover, in each of the manufacture approach of the rare-earth-elements dope Si ingredient by above-mentioned this invention, an erbium is used as rare earth elements.
[0012]
[Embodiment of the Invention] Hereafter, based on an attached drawing, the gestalt of operation of the rare-earth-elements dope Si ingredient by this invention and its manufacture approach shall be explained to a detail.
[0013] by the way, the luminescence mechanism of the atom of the rare earth elements in a semi-conductor is now -- it is not solved clearly. For this reason, although many researches which add an erbium into Si ingredient and observe a luminescence property were reported in recent years, luminous efficiency was low because of un-solving [of the above-mentioned luminescence mechanism], and there was a trouble that it would not have resulted by the time it uses.
[0014] However, research of the optical property of the semi-conductor which doped the erbium as rare

earth elements from about ten years before was tackled, the erbium clarified the location occupied into a parent ingredient, the energy transfer process, etc., and the applicant had full knowledge of sample production and the evaluation means of this system, and was able to get the rare earth dope Si ingredient with high luminous efficiency.

[0015] namely, in Si ("the nano microcrystal Si" is called hereafter.) constituted with the microcrystal of the magnitude whose dimension of a crystal is 3-5nm A quantum size effect will show up, the property as an electronic wave appears notably, and bulk-like Si ingredient is a different thing which will show optical and electrical characteristics. An applicant The nano microcrystal Si thin film with a mean particle diameter of 3nm was manufactured, and strong blue luminescence of Si ingredient was realized at the room temperature for the first time in the world (refer to JP,7-237995,A). Although luminous efficiency is very high and this luminescence does not deteriorate in a room temperature or very low temperature, either, this outstanding optical property is based on the direct transition between quantum level.

[0016] In order to raise the luminous efficiency of the rare earth elements doped by Si ingredient here, it is important what the interaction of the rare earth elements and host crystal which are doped by the host crystal slack Si crystal can be strengthened.

[0017] That is, when an erbium is chosen as rare earth elements, in order to raise the luminous efficiency of the erbium doped by Si ingredient, it is important what the interaction of the erbium and host crystal which are doped by the host crystal slack Si crystal can be strengthened.

[0018] Luminescence from erbium ion takes place by transition between the crystal field fission level of the electron of 4f orbit in the inner shell of an erbium atom. Fundamentally, by crystal field, the symmetric property of an erbium atom decreases and transition probability increases. Moreover, transition probability is proportional to the density of states of the level which changes. then, the applicant doped the erbium of a piece to the nano microcrystal of a piece, paying attention to having boiled markedly the density of states of the quantum level of a parent nano microcrystal for the fall of the crystal field symmetric property by the hyperfine structure according to the scale and the quantum size effect, raised the energy transfer effectiveness of an erbium and succeeded in ingredient production with sufficient luminous efficiency.

[0019] According to the experiment of an applicant, it formed as a nano microcrystal Si which formed Si of a parent ingredient with the super-microcrystal of nm order, and by the interaction of 4 f electrons and the electron confined in Si quantum dot, the energy transfer to an erbium emission center was performed efficiently, and efficient-ization of luminescence of it was attained.

[0020] 1.55-micrometer emission spectrum of the nano microcrystal Si which doped the erbium is shown in drawing 1 . Sharp luminescence as the main luminous efficiency of an erbium raised by this experiment and shown in drawing 1 has been observed to the room temperature. If this erbium addition nano microcrystal Si ingredient is used, Si light emitting device which operates at a room temperature can be manufactured for the first time. In the nano microcrystal Si which doped such an erbium, the both sides of blue luminescence by the nano microcrystal Si and luminescence with a wavelength [by the erbium] of 1.55 micrometers can be discovered, and the luminescence mechanism in the nano microcrystal Si which doped the erbium is based on the interaction of the inner shell level of an erbium, and quantum level.

[0021] That is, excitation of an erbium emission center takes place by the energy transfer from the electron excited by the quantum level of the nano microcrystal Si used as a parent ingredient, and the reverse process also exists. In the nano microcrystal Si, direct transition is remarkably amplified by the quantum size effect, and visible blue luminescence at a room temperature is observed strongly (refer to JP,7-237995,A).

[0022] In the nano microcrystal Si which doped such an erbium, since blue luminescence from the nano microcrystal Si has the luminescence life very as quick as hundreds picoseconds, ultra high-speed excitation is possible for it. On the other hand, the luminescence life of luminescence with a wavelength [by the erbium] of 1.55 micrometers is one or more mses, and no less than 6 figures are longer than blue luminescence from the nano microcrystal Si (refer to drawing 2). That is, the information written

to erbium level can be held to 1 ms using the excitation to visible blue luminescence level. That is, since 1 ms as a luminescence life of an erbium is die length sufficient as memory time amount of DRAM of a computer, it can use erbium level enough as memory of light (refer to drawing 3 (a)). Moreover, read-out of the data recorded on erbium level will re-excite an erbium, and will take it out as luminescence of a parent ingredient (drawing 3 (b)). For a certain reason, one or more mses of time amount whose erbium atom is in excitation level can serve as a suitable medium which records optical data.
[0023] That is, it becomes possible by doping an erbium to the nano microcrystal Si to accumulate an electronic circuitry and an optical circuit on Si substrate with the nano microcrystal Si which could create the optical device which emits light on blue luminescence and the wavelength of 1.55 micrometers, therefore doped the erbium.
[0024] That is, the nano microcrystal Si (nano microcrystal Si:Er) which doped the erbium can be constituted from on Si substrate, in the optical memory constituted by nano microcrystal Si:Er, can make light of rewriting or read-out the light, and can perform an informational output by 1.55 micrometers of the minimum transfer loss wavelength of an optical fiber. That is, in Si of a single crystal, since the probability of luminescence-transition is very low and transfer of the energy to erbium level also has low effectiveness, strong luminescence from an erbium cannot be expected but informational R/W is also almost impossible. however -- nano microcrystal Si:Er -- the interaction of quantum level and an erbium inner shell electron -- erbium level -- a high speed -- excitation -- or it can re-excite, and the information can be written by the blue glow of the light, can be read, or can be carried out.
[0025] In addition, in order to constitute optical memory as an optical device using nano microcrystal Si:Er For example, as shown in drawing 4 (a) and (b), the array 14 of the cel 12 of nano microcrystal Si:Er (nc-Si:Er) is formed on the Si substrate 10 (drawing 4 (a)). What is necessary is for a detector 18 to detect luminescence from a cel 10, and just to read information, while irradiating laser 16 and writing information in each cel 12 of nano microcrystal Si:Er (drawing 4 (b)).
[0026] Moreover, as shown in drawing 5 , the array 14 of the cel 12 of nano microcrystal Si:Er (nc-Si:Er) may be formed on the Si substrate 10 like the case of drawing 4 , and information on a cel 10 may be written in according to a current, and you may constitute so that a detector 18 may detect luminescence from a cel 10 and information may be read.
[0027] Although optical memory can be constituted as an optical device using nano microcrystal Si:Er as described above, as optical devices other than optical memory, the wavelength converter shown in drawing 6 can be constituted, for example.
[0028] That is, in the wavelength converter shown in drawing 6 , by carrying out incidence of the light information by which outgoing radiation is carried out from laser or LED to nano microcrystal Si:Er (nc-Si:Er), light information can be changed into the optical information on 1.55-micrometer wavelength (the minimum transfer loss wavelength of an optical fiber), and it can input into an optical-fiber system.
[0029] In order to manufacture the above-mentioned thin film of nano microcrystal Si:Er, two kinds of following approaches can be used.
[0030] That is, the 1st approach is the approach of manufacturing the nano microcrystal Si which carries out the ion implantation of the erbium into the amorphous silicon thin film of a high grade, and uses an erbium atom as a nucleus. By this approach, the erbium atom of a piece can be doped to Si dot of a piece, and the energy transfer from the nano microcrystal of a parent is improved.
[0031] The 2nd approach produces the microcrystal of Si from Si target of direct erbium addition using laser ablation. this approach -- nano microcrystal Si:Er -- a large area -- and it can manufacture thickly.
[0032] Moreover, luminescence of an erbium shows the fixed value by 1.55 micrometers also at very low temperature or a room temperature, and it is shown that this property can serve as a probe with which erbium luminescence investigates the physical properties of a parent ingredient. That is, since an erbium is excited by the energy transfer from a parent, a nonluminescent parent ingredient can also make an erbium emit light, and it can use this luminescence for a probe for it.
[0033] For example, when absorption of a microcrystal is hidden by existence of an ingredient whose luminescence energy and absorption end like porous silicon do not correspond, and an amorphous field like Microcrystal Si, the absorption end or forbidden-band width of face of a parent ingredient can be

measured for luminescence of an erbium to a probe. It is the graph which showed that drawing 7 could measure the forbidden-band width of face Eg of parent porous silicon from the excitation property of erbium luminescence. Drawing 7 (a) is the excitation property of erbium luminescence of porous silicon and visible luminescence of porous silicon which added the 1 cask of sample erbium (Er). Drawing 7 (b) is the excitation property of erbium luminescence of porous silicon and visible luminescence of porous silicon which added the 2 casks of sample erbium (Er), and the excitation energy dependency of erbium luminescence and the dependency of the excitation energy of parent porous silicon are shown. An erbium and porous silicon have the same absorption end, and its absorption end of erbium luminescence corresponds with the forbidden-band width of face Eg of parent porous silicon as shown in drawing 7 (a) and (b). Therefore, even if it cannot observe luminescence of porous silicon, Eg can be identified by this approach. If luminescence energy not only like porous silicon but an erbium uses 0.8eV (1.54 micrometers) and a small probe, it is effective as a probe of many ingredients, especially the charge of an admixture.

[0034] That is, although drawing 7 (a) and (b) showed the porous silicon which emits light to the example, if the parent ingredient which does not emit light also measures the absorption end of erbium luminescence, the forbidden-band width of face Eg of a parent ingredient will be decided.

[0035] In addition, in the above, although the case where an erbium was used as rare earth elements was explained, of course, rare earth elements other than an erbium may be used.

[0036]

[Effect of the Invention] Since this invention is constituted as explained above, it does so the outstanding effectiveness that luminous efficiency is high and the applicable rare-earth-elements dope Si ingredient and its manufacture approach to an optical device can be offered.

[Translation done.]

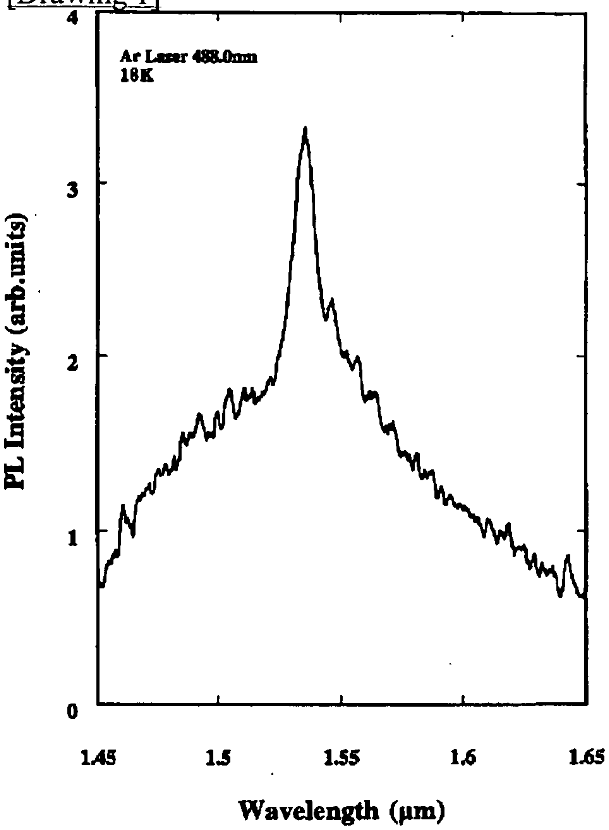
CLAIMS

[Claim(s)]
[Claim 1] The rare-earth-elements dope Si ingredient characterized by the ability to discover visible luminescence of Si ingredient which doped rare earth elements into Si ingredient formed with the super-microcrystal, and was formed in it with said super-microcrystal, the infrared rays of said rare earth elements, and visible luminescence.
[Claim 2] The rare-earth-elements dope Si ingredient according to claim 1 said whose rare earth elements are erbiums.
[Claim 3] The manufacture approach of the rare-earth-elements dope Si ingredient characterized by carrying out the ion implantation of the rare earth elements into the amorphous silicon thin film of a high grade, using the atom of rare earth elements as a nucleus, and manufacturing a rare-earth-elements dope Si ingredient.
[Claim 4] The manufacture approach of the rare-earth-elements dope Si ingredient directly characterized by manufacturing a rare-earth-elements dope Si ingredient from Si target of rare-earth-elements addition using laser ablation.
[Claim 5] The manufacture approach of a rare-earth-elements dope Si ingredient given in any 1 term of claim 3 said whose rare earth elements are erbiums, or claim 4.

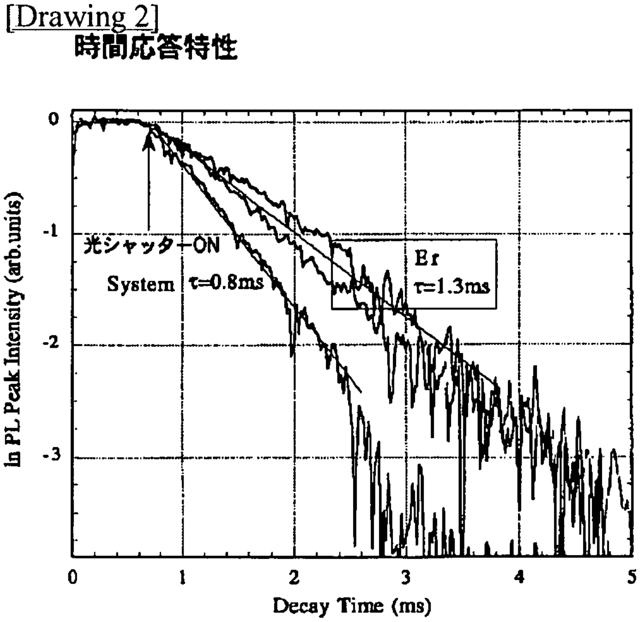
[Translation done.]

DRAWINGS

[Drawing 1]

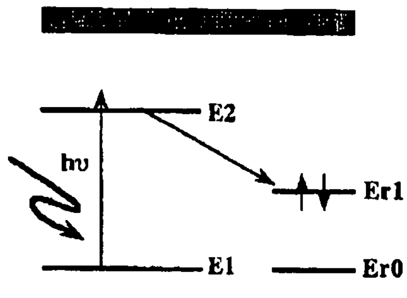


[Drawing 2]



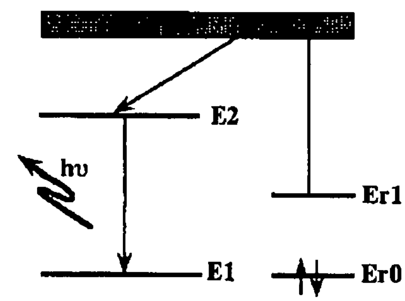
[Drawing 3]

(a)



Writing data: State 1

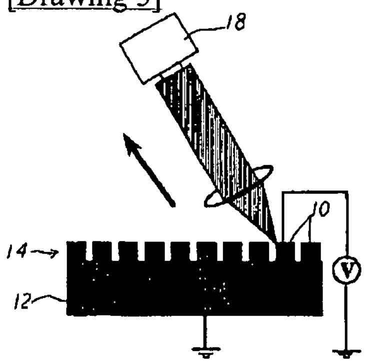
(b)



Reading data: State 0

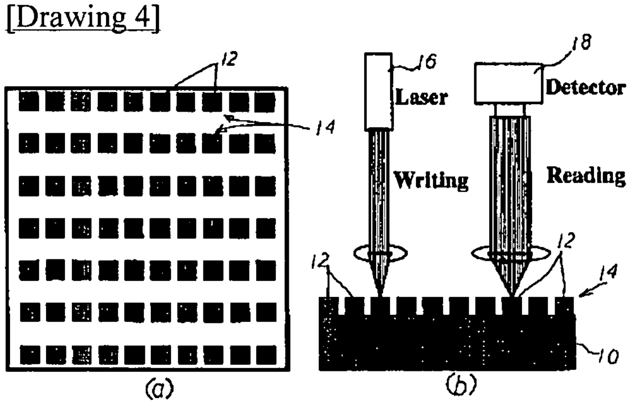
An Er optical memory cell

[Drawing 5]



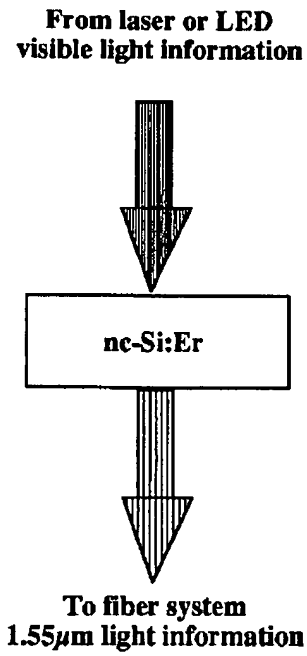
A nc-Si:Er memory array writed by current and read by light

[Drawing 4]



A nc-Si:Er memory array

[Drawing 6]



A nc-Si:Er wavelength converter

[Drawing 7]